Protecting Plain Old Telephone Customer Premise Equipment with a TISP®

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This engineering note has been written to provide the Engineer with a first principles theory when designing twisted-pair, Plain Old Telephone Service (POTS) equipment such as the telephone, fax or modem. Telecom chipsets are now commonly used in the front-end of these applications where protection against lighting disturbances is a key concern for increased reliability of the equipment and ensuring telecom standards conformance.

Telecom standards for Customer premise equipment

The countries standards or recommendations govern what protection is required for Customer Premise Equipment (CPE). CPE needs to conform to the specifications defined for the country where the USA equipment is required to meet TIA-968-A for lighting and UL 60950 (UL 1950) for a.c power line cross. Most other countries have adopted the ITU-T recommendations. The ITU-T K.21 document is pertinent to CPE equipment and uses the test circuits defined in ITU-T recommendation K.44. These recommendations have gone through a major iteration in year 2000 to include a higher (enhanced) test level for locations that have severe lighting currents and a primary and secondary protection impulse co-ordination test. More information is available in the article The new ITU-T Telecommunication Equipment Resistibility Recommendations by Mick J. Maytum and a copy is available from Bourns.

USA Customer Premise Equipment Requirements

The TIA-968-A is has two types of lighting surge test, A and B. Type A has been designed to test for any high stress failure mechanism of the CPE. The test allows equipment to fail, but only in a safe mode that is not harmful to the network. Any protection failure must be an open circuit condition making the CPE noticeably unusable after the surge. Type A metallic (transverse) testing applies two surges (one of each polarity) between any pair of line connectors on which lighting surges may occur. This test will be applied between Tip to Ring connections. For a 4-wire connection that uses simplexed pairs for signaling, additional impulse test is required between Tip to Ring1 and Ring to Tip1. The impulse voltage and current waveform is a 10/560 µs with an open circuit voltage of 800 V and current of 100 A. For longitudinal applications, voltage surges between the conductors and earth grounding connections and to all leads intended for connection to non-registered equipment. Longitudinal testing uses a different 10/160 µs test waveform with a peak open-circuit voltage of 1500 V and short circuit current of 200 A.

TIA-968—A Specifications	Wave Shape (t1/t2 µs)	Open circuit voltage	Short circuit current	Surge Type
Longitudinal	10/160	1500 V	200 A	A
Metallic	10/560	800 V	100 A	
Longitudinal	9/720, (5/320)	1500 V	37.5 A	B
Metallic	9/720, (5/320)	1000 V	25 A	

Type B surges reflect normal lighting surge exposure and the CPE must not degrade or fail during these tests. The metallic test (one of each polarity between Tip to Ring) uses a 9/720 µs, 1000 V open-circuit voltage with 5/320 µs, 25 A short circuit current. Longitudinal tests use the same generator, but with an open-circuit voltage of 1500 V and short circuit current of 37.5 A.

Selecting over-voltage protection

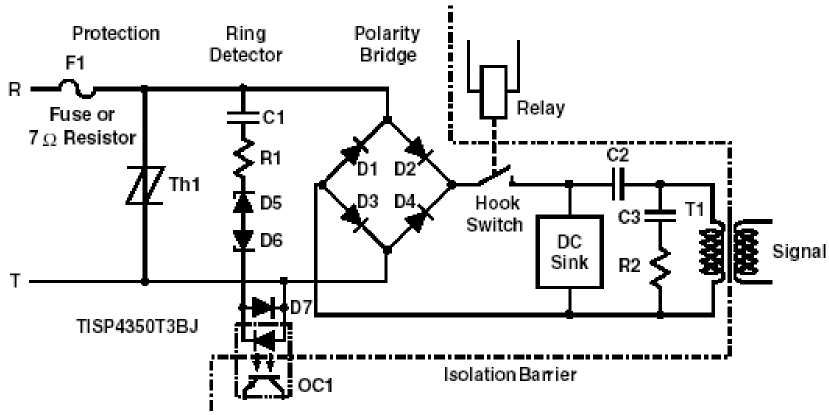

Figure 1. Telephone/FAX Protection

The maximum working voltage (V_{DRM}) of the thyristor needs to be considered to ensure there is no clipping during normal system operation. TIA-968-A in the USA requires a minimum V_{DRM} of —269 V (V_{PEAK}= -56.5 V + (-150 V x $\sqrt{2}$) to work with a battery-backed B type ringer voltage levels. Low ambient temperatures also need to be considered for reliable operation. The thyristor s V_{DRM} value decreases as the ambient temperature falls. To work down to 0 ^oC ambient, the thyristor s V_{DRM} should be rated for at least ±275 V at 25 ^oC. If lower operating ambient temperature, T_{AMIN} is required, the 25 ^oC ambient V_{DRM} selection can be calculated by using a temperature coefficient of —0.000846/°C.

$$V_{DRM\,@\,25^o C} = \frac{V_{PEAK}}{1-\left(0.000846 \bullet \left(25^o C - T_{AMIN}\right)\right)}$$

The protection voltage, $V_{(BO)}$ of the thyristor is set by the maximum voltage rating of the DAA (Data Access Arrangement) chipset or hook switch. The hook switch is now commonly implemented using either a transistor or opto-coupler. A 400 V switch transistor will require a thyristor protection voltage to be limited to ±350 V. 15 % of headroom between the maximum withstand voltage and $V_{(BO)}$ of the thyristor to provide reliable operation under extended temperatures.

Some DAA chipsets have a maximum switch transistor rating of 300 V and therefore a thyristor with a protection voltage $V_{(BO)}$ of ±290 V or lower should be considered. The TISP4290M3BJR has an impulse break-over voltage rating of ±298 V. However, this has a minimum V_{DRM} of ±220 V and ring clipping could occur under the type B ringer conditions. The type B ringer levels are historical and in practice with a —60 V battery and 100 V rms ring, a V_{DRM} of 200V will be suitable in most applications. If high temperature operation is required, a thyristor with a $V_{(BO)}$ of ±265 V (V_{DRM} = 200 V) should be considered to provide the additional 15 % of voltage headroom.

Selecting over-current protection

Most applications also require an over-current protector for high current a.c power line cross tests. If a fuse is deployed, then the thyristor needs to be rated for the impulse short circuit currents applied. In the case of the TIA-968-A, the thyristor needs to meet 100 A at 10/560 µs for metallic (2-wire applications). Bourns TISP4350T3BJR would be a suitable thyristor to consider in this instance.

Fuses for the UL 1950/60950 power cross need to break 40 A at 600 V a.c where ordinary fuses will not do this safely. Suitable fuses will be specified for breaking capabilities of 40 A, 7 A and 2.2 A at 600 V a.c. The fuse I^2t must be less than 100 A^2s to ensure conformance. Modems operationally passing the type A surge will tend to use a 1.25 A surge resistant fuse, such as Bourns B1250T.

$$I_{PP} = \left(\frac{V_{GEN}}{R_{SERIES} + \left(\frac{V_{GEN}}{I_{PEAK}} \right)} \right)$$

Applications that require co-ordination with the primary protector or where resetability is desired in the application, Polymer Positive Temperature Coefficient (PPTC) thermistors can be used. The resistance increases significantly under an a.c over-current condition, thus limiting the current into the circuit. The additional series resistance of the PPTC thermistor can allow the use of a lower current rated thyristor.

The TIA-968-A type A surge for metallic applications specifies a maximum voltage (V_{GEN}) of 800 V, with a short circuit current (I_{PEAK}) of 100 A. The impulse tester will have a fictive impedance of 8 Ω. Placing a 7 Ω current limiter in series with the generator fictive impedance will reduce the thyristor current to 53 A (I_{PP}). Therefore a thyristor rated lower than 100 A, but above 53 A could be used. The TISP4350MMBJR could be considered which has 10/560 µs rating of 55 A. The TISP4350MMBJR s 65 A 9/720 µs impulse rating will also ensure Type B impulse survival. An application deploying a PPTC thermistor with a minimum series resistance of 3 Ω would produce an I_{PP} of 73 A allowing the use of a TISP4350M3BJR which has a 75 A 10/560 µs rating.

	Thyristor Impulse Rating			TIA-968-A Metallic	
Device	10/160 µs	10/560 µs	10/700 µs	A	B
TISP4350T3BJ	150 A	100 A	120 A	0	0
TISP4350M3BJ	120 A	75 A	100 A	3 Ω	0
TISP4350MMBJ	75 A	55 A	65 A	7 Ω	0

Programmable over-current protection

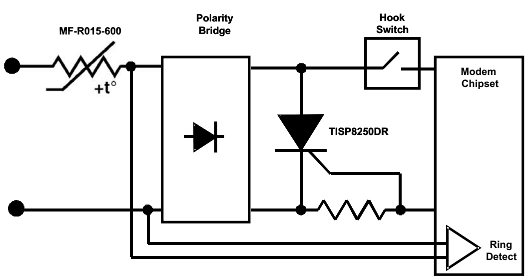

Figure 2. Overcurrent protection

Some CPE designs also have over current limitations. These designs can be damaged by a.c alone without ever reaching the protection voltage limit. In some cases, such as opto-coupler hook switches, using a lower protection voltage thyristor will solve the problem. A standard over voltage protection approach using a TISP4350MM3BJR as highlighted in Figure 3, allows a.c voltages up to 250 V rms. In this low current condition, the circuit current may cause equipment failure without operating the over current protection.

Figure 2 shows a current triggered protection design, where a current sense resistor and gated thyristor are used to monitor the line current. The resistor needs to be selected to ensure that normal loop currents and ambient temperatures do not trigger the thyristor. Gated thyristors normally have a minimum and maximum gate-cathode voltage (V_{GK}) values at a forced gate current. These are usually between 0.6 V to 1.2 V at 25 °C. At high ambient temperatures, the gate-cathode voltage threshold drops to about 0.35 V. A 5 Ω current resistor will avoid false triggering for line currents up to 70 mA and current triggering for peak currents of over 240 mA. In the voltage protection mode, the TISP8250D has a working voltage, V_{DRM} of 250 V and a protection voltage, $V_{(BO)}$ of 340 V. This thyristor will protect 390 V and higher rated hook switches. The TISP8250D can have its protection voltage lowered by the connection of an appropriate voltage zener diode between the thyristor Gate and Anode.

Appendix A

Basic Operation of the Telephone

The telephone was designed by Alexander Graham Bell in 1876 and has become an integral part of our lives, but the basic operation has not changed significantly since its first introduction. Voice is converted into electrical signals by the use of a microphone who s resistance changes depending on the sound wave. The telephone is biased with a negative battery voltage and therefore the varying resistance of the microphone is converted in to a varying current. This current allows the signal to be transmitted along the telephone line to the central office or PABX (Private Automatic Branch Exchange) for re-distribution. Communication from the exchange involves electrical signals that are sent back to the telephone and converted into voice by the speaker in the handset. Generating the electrical signals to allow speech to be sent to the telephone is achieved by using a Subscriber Line Interface Circuit (SLIC) that is essentially a line driver.

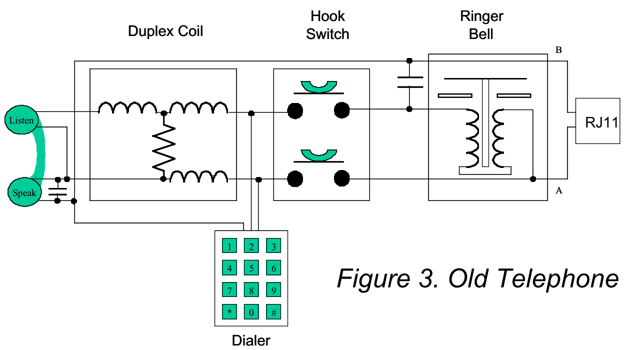

Figure 3. Old Telephone

The negative battery voltage or —V_{BAT} used to be provided by 12 V lead-acid batteries in series to provide —48 V. These are still sometimes used today for mains supply failure back-up purposes, but the negative battery is now achieved with off-line power supplies. The Telephone has an off-hook switch that informs the exchange when the telephone receiver has been picked-up. When a call wants to be placed, the hook switch closes the circuit and allows a loop current that informs the exchange that you want to make a call. The central office responses back to the telephone with a dial tone. On dialing the telephone numbers, a series of current pulses is defined for each number that the exchange identifies. When a call wants to be received, the exchange provides a ring voltage for ringing the bell on the telephone. When the receiver is picked-up, this interrupts the loop current and the exchange switches the SLIC onto the telephone line to allow communication.

Modern telephones use integrated chipsets that provide the speech, dialer and ringer functions. Moving coil or piezoelectric microphones are now used in the telephone.

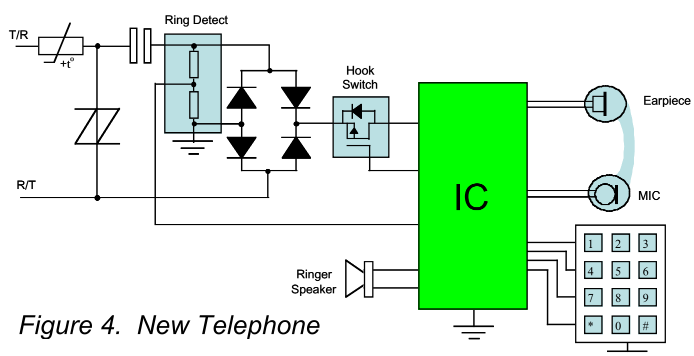

Figure 4. New Telephone

A ringer circuit is now deployed where the IC will drive a loud speaker rather than a traditional bell associated with old telephones. The a.c voltage to provide the ring has not changed where battery-backed (ring voltage referenced to battery voltage) ringing systems being the most popular deployed by the exchanges today. At least 40 V rms is required to ring the telephone and therefore voltages from 40 V to 100 V rms are common. The negative battery feed voltage can also vary from —24 V to —60 V and both depend on the required line length between the line card and the phone. These voltages are also usually limited by the regional telecom standards. The FCC type B Ringer defines a maximum of —56.5 V d.c and 150 V rms for the USA.